1. Fundamental Concepts

System Types:

- **Closed:** Mass constant, energy crosses boundary.
- **Open:** Mass and energy cross boundary.
- **Isolated:** Neither mass nor energy crosses boundary.

Zeroth Law: If body A is in thermal equilibrium with C, and B is with C, then A and B are in thermal equilibrium.

Equation of State (Ideal Gas):

$$PV = nRT = mR_{spec}T$$

2. First Law of Thermodynamics

For a closed system undergoing a cycle:

$$\oint \delta Q = \oint \delta W$$

For a process:

$$Q - W = \Delta U + \Delta KE + \Delta PE$$

Differential form (simple compressible system):

$$dU = \delta Q - \delta W = \delta Q - PdV$$

Enthalpy definition:

$$H = U + PV$$

3. Second Law of Thermodynamics

Kelvin-Planck Statement: No heat engine can convert all heat input to work.

Clausius Statement: Heat cannot spontaneously flow from cold to hot.

Entropy Change (ΔS):

$$\Delta S = \int \frac{\delta Q_{rev}}{T}$$

Inequality of Clausius:

$$\oint \frac{\delta Q}{T} \leq 0$$

4. Thermodynamic Relations

Maxwell Relations:

$$\left(\frac{\partial T}{\partial V}\right)_S = -\left(/\frac{\partial P}{\partial S}\right)_V$$

$$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$$

$$\left(/\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial P}\right)_T$$

5. Heat Capacities

At constant volume:

$$C_v = \left(\frac{\partial U}{\partial T}\right)_V$$

At constant pressure:

$$C_p = \left(\frac{\partial H}{\partial T}\right)_P$$

Ratio of specific heats:

$$\gamma = \frac{C_p}{C_v}$$